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Macro-economic impact of large-scale deployment of biomass resources for energy and materials on a national level—A combined approach for the Netherlands

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HIGHLIGHTS

- We analyse large scale production of bioenergy and biochemicals in the Netherlands.
- The scenarios include up to 30% substitution of fossil fuels by biomass in 2030.
- Resulting in strong greenhouse gas savings and positive macro-economic effects.
- Large amounts of imported biomass are required to meet the domestic demand.
- This requires high rates of technological change and strict sustainability criteria.

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ABSTRACT

Biomass is considered one of the most important options in the transition to a sustainable energy system with reduced greenhouse gas (GHG) emissions and increased security of enegry supply. In order to facilitate this transition with targeted policies and implementation strategies, it is of vital importance to understand the economic benefits, uncertainties and risks of this transition. This article presents a quantification of the economic impacts on value added, employment shares and the trade balance as well as required biomass and avoided primary energy and greenhouse gases related to large scale biomass deployment on a country level (the Netherlands) for different future scenarios to 2030. This is done by using the macro-economic computable general equilibrium (CGE) model LEITAP, capable of quantifying direct and indirect effects of a bio-based economy combined with a spread sheet tool to address underlying technological details. Although the combined approach has limitations, the results of the projections show that substitution of fossil energy carriers by biomass, could have positive economic effects, as well as reducing GHG emissions and fossil energy requirement. Key factors to achieve these targets are enhanced technological development and the import of sustainable biomass resources to the Netherlands.

1. Introduction

The transition to a sustainable energy system with strongly reduced greenhouse gas (GHG) emissions and improved security of supply requires major changes. Substitution of fossil energy carriers by biomass is considered one of the most important options (IPCC, 2007; IPCC, 2011; Beurskens and Hekkenber, 2011) and is expected to account for more than half of the 20% renewable energy target of member states in the EU-27 in 2020 (Atanasiu, 2010). In the Netherlands, the energy transition platform 'Bio-based Green Materials' has set ambitious targets to replace 30% of fossil primary resources with biomass in 2030 of which 60% substitution in the transport sector, 25% substitution in chemical sectors, 25% substitution in electricity and 17% substitution in heat (Rabou et al., 2006).

The transformation to an energy system – including large scale use of biomass for electricity, heat, transport fuels and materials – implies large investments and financial support in infrastructure and conversion capacity. Shifts in the use of imported and indigenous fossil resources, such as natural gas or oil, to imported, and domestic biomass resources, will also results in (major) sectoral shifts in the economy. Furthermore, investments in infrastructure and technology

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will generate new economic activities. This especially holds true when (low cost) imported biomass resources are converted into high value added products such as bio-chemicals and replace relatively expensive fossil-based resources that have to be imported (Brehmer et al., 2009). On the other hand, the large scale use of bio-based materials can also induce negative effects such as (indirect) land use changes (Melillo et al., 2009; Edwards et al., 2010) or increased prices in competing markets (Beckman et al., 2011). A better understanding of these impacts is of vital importance for designing targeted policies and implementation strategies to optimise the economic benefits and reduce risks (costs) of large scale biomass deployment.

The Netherlands depend to a large extent on the import and export of raw materials, intermediates and final products. Therefore, a multidisciplinary modelling framework should be used to encompass the interactions among sectors within economies and among countries through international trade of biomass and fossil energy carriers. At the same time, this model should be able to address the technological detail and technology changes that underlie these sectoral changes. Recent concerns on the negative impact of biomass for bioenergy, including food prices and (indirect) land use change induced by biofuel production, has led to major efforts to incorporate biomass for bioenergy and the related technology details into macro-economic models (Wicke et al., 2012). Despite recent efforts to improve macro-economic models to estimate the global land use impacts of biofuel production, there are still large uncertainties and shortcomings to these models. One of the main shortcomings of these models is the representation of conversion technologies, type of crops used and by-products and co-products that are produced (Wicke et al., 2012). Furthermore, most of these models focus on biofuels for transport only whereas bio-based electricity, heat and, potentially, also bio-based chemicals are also important sectors for current and future uses of biomass resources.

The aim of this article is to provide quantitative insight on the impact of the large-scale substitution of fossil-energy carriers with biomass in electricity, transport and chemical sectors on a national level for the Netherlands to 2030 using the macro-economic computable general equilibrium (CGE) model LEITAP. A spread sheet tool provides the required input data of the LEITAP model and to analyse and compare the results with bottom-up projections to identify key uncertainties and limitations of the selected approach.

Although imports of biomass from European and non-European countries are taken into account, the main focus of this article is on national impacts related to bio-based substitution of electricity, chemicals and transport fuels. Possible positive or negative (indirect) effects outside the Netherlands are highly relevant, but to assess these effects, would require a larger regional or global scope with all related uncertainties on socio-economic, political and technological development.

2. Methodology

Detailed assumptions on the substitution of fossil electricity, transport fuels and chemicals with domestic and imported resources are implemented in the top-down computable general equilibrium model LEITAP to estimate the potential macro-economic and environmental impact for the Netherlands. To assure more comprehensive technology details, physical parameters in LEITAP have been updated with an Excel based spread sheet tool.

2.1. Scenarios

This analysis includes four main scenarios, partly consistent with the storylines and scenario variables of the IPCC SRES scenarios 'Global Economy,' 'Continental market,' 'Global cooperation,' and 'Regional communities' (IPCC, 2011) and one additional scenario with a focus on bio-based chemicals. The scenarios vary over two key variables: (1) international cooperation & trade and (2) technological development rate (Fig. 1). In the scenarios with more global orientation (GlobLowTech and GlobHighTech scenarios), it is assumed that biomass resources are available for the Netherlands at global level, whereas for the scenarios with more regional orientation, the biomass market is limited to European resources of biomass ('RegLowTech' and 'RegLowTech' scenarios). Conversion technologies in the scenarios with conservative technological development (LowTech) are assumed only to have technologies available that are already used commercially today. For the scenarios with enhanced technological development (HighTech), advanced conversion technologies, such as second generation biofuels and advanced bio-refinery concepts, are assumed to become available by 2015. The GlobHighTechAC scenario is similar to the GlobHighTech scenario, but includes, apart from bio-based hydrogen, also the chemicals bio-based ethylene and caprolactam to substitute 25% of fossil raw materials in the chemical sectors in 2030. Scenario assumptions other than bioenergy are derived from WLO scenarios (welfare, prosperity and quality of the living environment) that project different futures for the Netherlands within the IPCC SRES scenario framework (Janssen et al., 2006).

The technologies depicted in Fig. 1 represent the key conversion options per scenario. Table 1 summarizes all technologies available in the scenarios. The technical, environmental and economic performance of these technologies and related references for cost and efficiencies are provided in the Appendix and in Hoefnagels et al. (2009).

2.1.1. Electricity

The selected technologies include representative biomass conversion technologies and their fossil counterparts already being used or that are expected to become available before 2030. Co-gasification of biomass in natural gas combined cycle plants (NGCC) represents advanced electricity generation that is only available in the high-tech scenarios from 2015 onwards. Co-firing of biomass in pulverized coal plants (PC) is available in all scenarios. Incineration of organic waste (MSW) is also available in all scenarios, but the future growth potential is limited. Wet organic waste (WOW) is assumed to be converted into electricity and heat via gas produced from anaerobic digestion.

For renewable electricity generation, the total potential depends mainly on the replacement rate of existing central power generation units (pulverized coal and natural gas) and related co-firing potentials and co-generation in case of advanced biomass technologies in the HighTech scenarios. Similar to Hansson et al. (2009), it is assumed that existing coal-fired capacities have a 10% fuel share of biomass, but for new capacities, 20% is assumed to be feasible. Replacement rates of existing capacities are based on the long vintage (LowTech) and short vintage (HighTech) scenarios of van den Broek et al. (2008). Future capacities are mainly based on the WLO-projections for decentral generation units such as CHP (Janssen et al., 2006) and own assumptions for central generation plants and biomass conversion units. Final energy demands are derived from the LEITAP projections. The resulting blending shares, as calculated with the spread sheet tool, in the scenarios are depicted in Table 2.

2.1.2. Transport fuels

The biofuel blending targets, as reported in the National Renewable Action Plan of the Netherlands (Government of the Netherlands, 2011), include blending shares that increase from 4.25% in 2011 to 5.5% in 2014. The growth rate after 2014 is yet